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Against Neoliberal Enclosure: Using a Critical Transdisciplinary Approach in Science Teaching and Learning

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ABSTRACT

This article offers a critical transdisciplinary heuristic as both a tool for critique of neoliberal reforms in schools, particularly in science and environmental education, and a springboard for the reconstruction of education along more equitable and sustainable lines. Emerging from the sociocultural study of science, critical pedagogy, critical youth studies, and participants' reflections on practice, this heuristic challenges hegemonic assumptions pervasive in science teaching, learning, and research by foregrounding the lived experiences of students. Two narratives demonstrate the potential of this heuristic in both a formal and an informal context.

Introduction

As neoliberal reforms have radically reshaped various sectors of public life, science education has also been altered. Neoliberal theory authorizes market-based solutions such as the deregulation and privatization of public services and industries, including education, to solve social issues (Picower & Mayogra, 2015). By misapplying standardized and efficiency-driven practices favored by businesses to education, neoliberal reforms have constrained the social imaginary of science education within the limits and contradictions of capitalism. To counter the climate of neoliberalism in science education, we offer a critical transdisciplinary heuristic to approach the teaching, learning, and research of science and related educational fields, such as environmental education.

We begin by situating science education within neoliberalism to demonstrate the ways that meritocracy and competition function to exclude minoritized students, and constrain and “enclose” spaces for learning. We then outline the six components of a critical transdisciplinary heuristic that offers an alternative to the individualistic, market-based rationale that currently dominates education. We follow by illustrating the heuristic's critical and liberatory potential through two distinct narratives: one in an informal learning setting and another in a formal learning setting. We then discuss, through reflecting on the narratives and the heuristic, three themes that emerged from our data: political neutrality; the purpose of science education; and liberatory models of teaching, learning, research, and resisting enclosures. We conclude by arguing that this heuristic is a response to the “enclosure” of neoliberalism, thus offering a way to expand possibilities for learning through integrating youth's lived experiences.

Neoliberal enclosure in science education teaching and learning

To understand why science education is susceptible to market-based reform requires an examination of neoliberal ideologies and how these ideologies are sustained as unquestioned norms (Bazzul & Siatras, 2011), which lead to enclosure in knowledge production. In using “enclosure,” we draw from

the notion of “the transformation of commonable lands into exclusively owned plots” (Vasudevan, McFarlane, & Jeffrey, 2008) and extend this understanding to science teaching and learning where the “lands” refer to knowledge and the processes of knowledge production.

Meritocracy, a social system based on intelligence testing that promotes individual educational and wealth attainment (Liu, 2011), is a key component of neoliberalism embedded in science education standards. Science standards, along with accountability testing, are widely believed to reduce inequality because they ensure that all students receive the same education. Yet most standards focus only on student achievement outcomes, while ignoring inequities in inadequate schooling (Au, 2009). For example, the Next Generation Science Standards were designed so that all students could learn specific interdisciplinary science concepts and build on those concepts in each consecutive year (National Research Council, 2012). The Next Generation Science Standards and other standards ignore that not all students have access to the same forms of capital. Schools that serve historically “minoritized” (Arpacik, 2015; Chase, Dowd, Pazich, & Bensimon, 2012; Shields, Bishop, & Mazawi, 2004) students often do not have resources such as labs, computers, and other technologies (Darling-Hammond, 2004) or access to science classes such as physics (Kelly & Sheppard, 2009). Thus, students attending a school that cannot fully support their success will be expected to achieve the same outcomes and compete for the same colleges and jobs as students attending more affluent schools, which are likely to have ample science classes and resources. Implicit in policies of standardized education is the notion of objectivity in measurement of student outcomes. In this way, neoliberalism in science education reproduces inequities that already exist between racially and economically marginalized students and their affluent counterparts (Tobin, 2011). Thus science and science education become enclosed—“privately owned” by those with racial and economic privilege.

In addition to the inequitable distribution of resources, the standards and concepts taught in science classrooms are presented as objective knowledge—accessible and relevant to all. However, Carter (2004) argued that the discipline of science is embedded in a Eurocentric ontology and axiology, which in essence privatizes knowledge and knowledge production. Accordingly, values and activities emphasized by science curricula and teaching practices are created for standard English-speaking middle-class and upper middle-class students of Euro-American descent (Lemke, 2001). This reproduction of Whiteness or Eurocentrism materializes in the classroom through what Bang, Warren, Rosebery, and Medin (2012) call a deficit discourse, or a climate that dictates what counts as “an acceptable explanation, argument, or analysis; what ‘smart’ looks and sounds like; whose narratives and experiences are valued and for what purposes” (p. 303). Deficit discourses appear in the classroom as a limited range of acceptable answers to questions. This restrictive meaning-making often devalues the knowledge(s) that youth of color bring into the classroom. This process potentially perpetuates the life cycle of deficit discourses and delegitimizes minoritized youth’s “lived experiences” (Cole, Nardi, & Vadeboncoeur, 2015; Weis & Fine, 2012). The fallacy of science as an objective process and product significantly disadvantages minoritized students as they are pushed out of science classes, majors, and ultimately science careers.

A critical transdisciplinary heuristic

In recognition of the systemic and epistemological violence enacted on youth by a neoliberal approach to science education and also our own participation in that system, we critically examine our practices and approaches to science teaching, learning, and research. Through reflection on our choices as educators, activists, scholars, and students, as well as through affiliation with liberatory theories and practices of education, we have sketched a critical transdisciplinary heuristic, which we describe in this section, to counter the neoliberal enclosure of science education. This heuristic continuously evolves as a result of our individual and collective reflexivity. Although we have gleaned most of our insights as educators working in urban settings, we view our heuristic as meaningful in all educational settings. Key aspects of this living heuristic draw from critical race

theory (Delgado & Stefancic, 2012), youth participatory action research (PAR; Cammarota & Fine, 2008), critical pedagogy (Darder, Baltodano, & Torres, 2009), and ecopedagogy and eco-justice (Bowers, 2002; Kahn, 2010). Equally important, we extend our use of transdisciplinarity from Basarab Nicolescu (2005), who argued that “transdisciplinarity concerns that which is at once between the disciplines, across the different disciplines, and beyond all disciplines. Its goal is the understanding of the present world, of which one of the imperatives is the unity of knowledge” (p. 2).

Through literature and praxis we have outlined a critical transdisciplinary heuristic with the following six parameters, which are neither fixed nor hierarchical: (a) Contextualize and historicize knowledge; (b) Challenge assumptions of neutrality and objectivity through critical inquiry; (c) Decenter hegemonic notions of knowledge production; (d) Situate place and space; (e) Privilege process over product; and finally (f) Promote participatory teaching, learning, and research. We view these parameters as useful challenges in guiding educators in their teaching and scholarship to help unsettle neoliberal reforms in science education.

Thus, the critical transdisciplinary (Crit-Trans) heuristic is situated in the notion that although we have different lived experiences and knowledge, we can work collectively to collaboratively critique and reconstruct educational research and practice. An enclosed and narrow framing of science fails to capture the historically, socially, and culturally situated nature of science. Using a more polysemic view of science, we argue that all students and educators bring valuable knowledge and expertise into a learning space, whether it is a formal classroom or informal context. Recognizing everyone as experts of their lived experiences and thus creators and holders of knowledge translates into an environment in which teaching and learning is a collective endeavor (Rosenfield, 1992). This recognition also requires us to relinquish the notion of teachers as gatekeepers of knowledge (Pedretti, Bencze, Hewitt, Romkey, & Jivraj, 2008) and to dismantle the conventional power structure of teacher as knower and student as learner, allowing all to be simultaneously teachers and students (Freire, 1993).

This heuristic also recognizes that teaching and learning cannot exist as separate from the social, political, and cultural structures that shape our institutions and larger society. An interdisciplinary and transdisciplinary understanding of interconnectedness allows students and teachers to interrogate how these structures influence their daily lives. In this way, science extends beyond the textbook and classroom into students' lives and communities in meaningful ways (Strong, 2016). Our goal is not to have students meet particular standards or pass standardized exams, but rather to cultivate students as active agents in investigating and improving quality of life for themselves and their communities.

This stance is in contrast to the rhetoric of neoliberal education reform where science has been touted as the means by which the United States can stay economically relevant and competitive in a global marketplace (Langdon, McKittrick, Beede, Khan, & Doms, 2011). For example, in 2006, the 21st Century National Defense Education Act was “to establish a comprehensive education program to bolster the economic competitiveness … of the United States by promoting science, technology, engineering, and math education, careers and capacity” (p. 1). In response, schools privilege competition among students, which extends to competition in the national and global labor market. To this point, Barton (2001) in conversation with McLaren argued,

Science education has become more about presenting students the science they need to fit into society rather than about educating students about how they might produce, use, and critique science to work with and transform society. Going to school does not enhance one's chances of success because even if everybody was learning something, schooling is still about stratifying students. (p. 848)

In this way, the teaching of science education reproduces the hegemonic structures that exist in society. Racially minoritized populations and women generally do not fare as well as their White, male counterparts in terms of access to and success in science fields, thereby reinforcing the narrative of who can be successful in society.

The opportunity exists, however, to reclaim and redefine science education as a tool to investigate the places that surround us—our local and intersecting environments. For that reason we developed the Crit-Trans heuristic to reframe science as a means of transformation through examining and documenting our lived experiences in a movement toward more liberatory praxis.

Counter-hegemonic science education reform

Transformation of science into a liberatory practice requires us first to identify and then deconstruct the hidden power structures embedded in science. McLaren argued in Barton (2001), “If we conceptually undress the role science plays in the larger society, we can see how it stabilizes dominant social relations” (p. 851). Thus in problematizing the linkage between science and progress, we can imagine new possibilities that transcend neoliberal reforms. Science is purported as a path to financial success; social status; and social, cultural, and intellectual capital (Liu, 2011). However, with only particular groups of people having access to the education, expertise, mentorship, and social and geographic capital that allows one to succeed in science, it cannot be called progress, but rather called hegemony (Kincheloe, 2011). This version of science education serves to maintain the status quo of knowledge, ideologies, and interests so that those with the access benefit at the expense and exploitation of those that do not have access.

We view our Crit-Trans approach to science education as counter-hegemonic. This approach should not be read as a pedagogical prescription, but rather a way of approaching science teaching, learning, and research to cultivate learning environments that foster creative transdisciplinary agency around knowledge production and enactment. In the following sections, we present two teaching narratives drawn from the teaching experiences of the authors—one example from an informal context and one from a formal context—that provide illustrations of how science education may look when enacted using a Crit-Trans heuristic. These narratives are based on data generated during ongoing participatory research in two environmental science-oriented learning experiences for youth. Two of the authors teach in the courses and bring their experiences to research group at the doctoral institution, where they, along with the other authors, discuss critical events and generate shared meanings from the perspectives as educators. These particular narratives were selected because they demonstrate the tensions that arose and led to deeper learning about our critical and transdisciplinary commitments in science teaching and learning.

Resisting enclosure in an informal setting

This section highlights aspects of a garden-based summer eco-justice program (Bowers, 2002) as an example of Crit-Trans science education. Our involvement in the program has been in the roles of founders, administrators, researchers, and instructors. Since 2004, this program has been offered on an urban public college campus and annually serves 20–25 urban public high school participants, who are selected based on their expressed interest in both learning and civic engagement around environmental issues. The population of students is reflective of surrounding communities whose members identify as Caribbean- or African American, Latina/o, South or East Asian. The youth range from 13 to 17 years old, and the majority identify as female.

For 7 weeks, students work with peer mentors (returning high school and college participants) and instructors to engage in gardening at nearby schools and public spaces. In the program, they engage in inquiry activities that allow them to connect food and farming to their lived experiences via themes such as community, food systems, resource access, public space, consumer culture, and social change. These themes are explored in place-contexts, and through the creation of written and visual artifacts to document aspects of their communities, and by interacting with other communities engaged in activities such as collective change within food co-ops, clean energy advocacy, up-cycling initiatives, and land stewardship projects.

A narrative of liminal gardening

By the first year, we realized that both the reasons for students' interest in the experience and the possibilities for program development in the garden were far richer than we had imagined. For instance, the students came (and continue to come) to the program from a wide range of ethnic and cultural backgrounds, bringing memories, stories, and knowledge related to food, land/place, culture, community, agriculture, and botany. Although we lacked a formal understanding of learner-centered pedagogies and theories, we quickly recognized that students brought impressive capacities on which to draw, both to enhance mutual learning and to develop pride and leadership. At times, we found it difficult to "get out of students' way," turning facilitation of discussions over to peer mentors or students, taking time to understand and be responsive to students' (not only our) learning goals, foregrounding their knowledge and experiences or foregoing my sense of what "should" come out of a given discussion in favor of often more powerful "emergent learning opportunities" (Rahm, 2002). Topics began to emerge from their questions and contributions, and by the 3rd year of the program, we were investigating global food systems through viewing and discussing films, writing, and taking field trips to food co-ops, supermarkets, and farm markets.

A turning point came several years into the program, when the continued existence of the garden that had generated many of the program's activities and themes was threatened. The college, which housed the community garden, announced that the land on which it had stood for 14 years was needed to expand campus parking. Therefore, it was to be moved to a much smaller space, effectively precluding composting, water catchment, and other ecological practices, as well as preventing large gatherings, such as a potluck community lunch—or a class. This would limit access to the garden not only for students, but also for the community members who had physically built and tended the garden for many years, breaching an implicit understanding between the college and community. After attempts at negotiation failed, a 2-year struggle involving community members, university administrators, college and high school students, faculty, visual and music artists, and the media resolved when the courts ruled in favor of the college. The garden was razed, and a smaller, college-controlled one was built in its footprint. An image-conscious press release proclaimed the college a "green," community-centered campus, the administration of which stood at the forefront of the sustainability movement.

During this period, program participants and other stakeholders connected to the garden raised serious questions that both personalized and deepened the critical bent of the program. Who owns public land, and whose needs should it serve? What responsibilities do public institutions have to the communities in which they are situated? Students began to recognize and challenge assumptions embedded in the actions of college administrators about the kinds of learning experiences and spaces deemed meaningful, why, and for whom. Perhaps most important, in wishing to defend a place and program that they themselves had imbued with meaning, students began to probe outlets for expression and representation and reached out to other politically marginalized groups, such as the community gardeners. They began to explore how these could be leveraged into change, and in doing so encountered and grappled with complex concepts such as "solidarity" and "intersectionality." Such struggles offered instructors and learners opportunities to interrogate and challenge hegemonic notions about education.

Brokering institutional relationships

In developing a framework for "critical place-conscious" education, Gruenewald (2003) delineated the barriers and contradictions that complicate relationships among the many schools and communities in which they exist. Along these lines, a major source of tension for the garden program had been its original location, which was also at the actual physical margin between the school and the community. This situation led to a serious limit situation, which Freire (1993) defined as a barrier imposed upon the oppressed that constrains their process of humanization

but may, through praxis, lead to conscientization, or the understanding of the social and political contradictions of their situation.

In the 2 years following the college's announcement of its plans to raze the garden, many of the program's themes—community, land/space, and social change, for example—emerged out of the period of collaborative struggle, perceived injustice, and sense of loss, which resonated with the lived experiences of many program participants. Although the original space was squashed, the community of gardeners, whose critical inquiries had been nurtured during the program, had cultivated a language within which to understand the college's economic bottom line and the political situation at hand. Had the instructors initially enforced a more politically neutral, instructor-led, product-oriented program in which youth learned decontextualized botanical skills and “green” rhetoric, the youth may not have flexed their will, buoyed by nuanced understandings, to resist the enclosure of their learning space.

As a response to the aforementioned events, the program now begins with two linked activities. The first is a narrated walking tour, starting at the college garden and ending at the two smaller school and community gardens where the program's gardening activities currently take place, to begin the practice of situating the summer experience in its historical and place-conscious contexts. Furthermore, student projects are self-generated and reflective of Crit-Trans learning. Recent topics have included educating community members about participatory budgeting; enriching health fairs at a local church and library with youth-led consumer workshops; organizing users of a local park to create a community garden; and organizing a youth-led response to the Common Core standards that would privilege young people's demands for learning goals, methods, and conditions. In explaining why they enjoyed the program so much, one student remarked, “We have actual discussions; our thoughts are taken into consideration. We are free of numbers.” When asked to explain “free of numbers,” the student explained that students are always told to write so many essays with so many paragraphs or do so many math problems. We are able to provide this environment partly because of the informal nature of the program and because we were able to leverage what could have been a limit situation into one where a Crit-Trans framework emerged and produced a transformative teaching and learning experience both for educators and students.

Enacting a Crit-Trans heuristic in a formal setting

Our second narrative illustrates critical work in an environmental science class, facilitated by another coauthor and conducted in collaboration with students at an environmentally focused urban public high school that serves more than 1,300 students. It is a college-credit bearing elective course and met for 90 min daily over the course of a full year. Students enrolled in the class have self-identified as American, Bengali, Dominican, Ecuadorian, African American, Indian, Mexican, Mixed, Polish, and Puerto Rican. This narrative highlights the struggle to release deeply entrenched ideas about what counts as knowledge and research in a formal education context.

The struggle to loosen the reigns

The shift was a challenging multiyear process, from leading a more disciplined and traditional environmental science class to a critical, local, participatory course focused on the lived experiences of youth. Prior to this, we taught a conventional environmental science course that relied on textbooks and placed a strong emphasis on global environmental issues, such as climate change, that deemphasized political and economic policies in favor of climate science and other related fields.

In the spring semester of 2012, as an initial gesture toward a more critical and transdisciplinary approach to science education, we introduced Photovoice (Bellino, 2015). Photovoice is a form of PAR, whereby marginalized social groups capture images and voice their concerns in hopes of creating awareness for themselves and others to spark change (Wang & Burris, 1997). We used Photovoice as a tool for youth to explore their local environments, but we were also determined to

have them generate a research question that they could investigate, and to write a formal scientific paper as a final product. Thus, we asked students to consider how they make meaning from their observations and interactions with their local environments. Students would gather images from their environments, discuss them in small groups, write individual narratives based on a small selection of their pictures, and in groups create a collective presentation of their theme. We imagined Photovoice as a means to reach the end project—a more formal “scientific” research assignment.

Not thinking about Photovoice as research in and of itself, we reduced Photovoice to a method of picture taking and dialogue that lacked any criticality. Although it was able to connect students to their lived experiences, it lacked any depth at discussing why particular conditions (e.g., litter, poverty, crime, gentrification) existed in their neighborhoods. Although we recognized the transformation that could take place in our classroom, we succumbed to the role of gatekeeper of knowledge (Pedretti et al., 2008). As the teachers in the classroom, we felt it was our responsibility to structure the entire Photovoice experience. We framed the goals of the project, selected the student groups, facilitated the small- and large-group discussions, dictated the research process, and demanded the final product be a traditional scientific-style research paper. Due to our inability to recognize students as producers of knowledge, they were only able to “engage in closed ended replication or verification kinds of inquiry, with little room for creativity, imagination or open-endedness” (Pedretti et al., 2008, p. 943). In a course reflection, one student (all names are pseudonyms) wrote,

Photovoice might be a technique to add your voice, but it does not mean we should devote time to such a technique in class. The process is not natural to my classmates and I. Students in the class have already been taken away from the purpose [of Photovoice] by having to do it on demand. What are we trying to convince the public of if we did not wish to tell them anything in the first place? I feel like my Photovoice has *no purpose* and I do not know how to stress that enough. (Candace, Spring 2012)

We implemented Photovoice like a traditional science lab, with succinct steps with a known outcome—“on demand,” as Candace wrote. Students were not afforded the opportunity to have a voice and feel empowered to expand Photovoice in ways that were meaningful to them and their lived experiences.

The final research projects varied in their criticality. Some emerged directly from the Photovoice images and discussed issues of power, race, gender, and class (e.g., Youth Perceptions of City Neighborhoods). Other final papers were closely tied to positivistic, causal models of research utilizing more quantitative data collection methods (e.g., Preferences for Nature Based or Recreational Activities in the Local Park). By the end of the year, many students viewed Photovoice as a waste of time.

By design, Photovoice is a participatory methodology rooted in epistemological assumptions about knowledge production and who has the right to research. Our first experience with Photovoice clearly went against the tenets of participatory research where the research inquiry is rooted in the needs, knowledge, and experiences of the participants (Mayorga, 2014). Although we knew that critical conversations were lacking in schools and believed that schools needed to create space for them, we were frightened of losing our power. We were aware of our fear and discomfort of having difficult conversations in the classroom, and this awareness prevented deeper inquiry. We were holding tightly to ideas about what it meant to be a teacher and to teach science, and as a consequence, these practices were doing a disservice to our students.

Through opening up these topics that shape the lives of students only to fall back into the rigidity of the science classroom, we were perpetuating the dominant narrative of what it meant to engage with science. The following year we taught the environmental science course again and were committed to having a more participatory classroom experience. We desired to create a community in our classroom that centered students’ experiences and knowledge and positioned them as the experts in the classroom and therefore as holders and producers of knowledge. Again, we used Photovoice to explore issues that were important to youth in their local environments, but this time we were able to recognize the power of the Photovoice research methodology and nurtured the process of research, rather than focus on the product. Throughout the process of taking pictures and

engaging in dialogues, issues rooted in sociohistorical processes including segregation, diversity, cultural and community identity, and access to resources, space, and housing emerged: a confluence of the social with the environmental. Throughout the second year, students were exposed to social and critical theory and were better able to connect their images to larger systemic issues that they could see in their neighborhoods. Through a process of individual and collective reflection, along with the connections to theory, various research themes emerged, such as gentrification, diversity, homelessness, privatization, loss of funding for parks, and housing.

In contrast to Candace's discomfort with Photovoice and its lack of purpose, Aurora's reflection the following year revealed the power of a participatory method that seemed natural to her and in accordance with her needs and experiences as a student:

Though I view the world as integrated, more specifically [our city], it's evident that there are still tensions concerning race and social class. I saw our conversations in class and all these Photovoice projects as controversial because we were forced to think and question things that we normally would just let lay. I see my neighborhood through a different lens because of photovoice. Society is constantly wrestling with itself, similar to how we have wrestled with the issues and questions presented from all these Photovoice projects. (Aurora, Final Reflection on Research Themes, 7 June 2013)

Aurora identifies two key components about the power of Photovoice as a participatory methodology and what it affords youth. First, Photovoice allowed her and other students to "to think and question things that we normally would let lay"; second, it allowed her to see her "neighborhood through a different lens." Both of these comments made by Aurora speak to the participatory, transformative, and critical nature of Photovoice and highlight the potential it has to contribute to pedagogy informed by a Crit-Trans heuristic.

By the third year of teaching this course, it looked and felt different. We used participatory data collection and analysis throughout all our investigations and learning experiences. We created maps of neighborhoods and engaged in critical conversations to collectively generate themes about youth living in urban environments. Students spoke in depth about their personal experiences with gentrification, the gendered experiences of youth both in the home and in the larger city, and the lack of access to healthy foods in different parts of the city. They investigated advertising and its messages, learning the tools of content analysis and critical discourse analysis. We watched films about inequality, capitalism, and neoliberalism; we discussed the American Dream and the myth of meritocracy; we talked about their own experiences as immigrants, the stigma of being on food stamps, and the stereotypes associated with living in housing projects. These were their "environmental" issues.

Reflecting on climbing the PAR ladder

In the first year, the Photovoice project was implemented as a linear process moving students from their images, to personal narratives, to group presentations, and then to research projects. In reflecting on the process, it was clear that students conducted their research projects in the way we had been taught to conduct research. The group presentations of Photovoice images were one-sided, not dialogic, and the discussion questions asked by students were used as writing prompts, rather than class discussion. Although many of the issues that students raised in their presentations and through their questions were deeply critical—"What stereotypes exist in your neighborhood, and how do you break them?" "What is one change in your community that has affected you either negatively or positively?" and "Throughout the city, why do we see differing access to green space?"—these questions were never explored collectively. Each group posed questions that reflected their concerns as young people. These questions could have generated ideas about how young people see themselves in relation to their neighborhoods and the greater city, but the class was not structured in support of such critical dialogue. Despite incorporating components of critical pedagogy and challenging the traditional notion of what counts as environmental science, our hesitation to truly center the voices and lived experiences of the youth in the class limited the class.



Crit-Trans PAR

We brought our experiences with facilitating Photovoice and other PAR methods into our research collective, and this has allowed us to become more familiar with the assumptions embedded in PAR and now recognize the ways we silenced students and cut short the power of PAR. Photovoice as a participatory methodology subscribes to the assumption that young people hold deep knowledge about their lives and experiences and should help shape the questions and frame the interpretation of research (Torre & Fine, 2006). In the first iteration of Photovoice, this assumption was ignored. The two student reflections reveal the differential experiences of Photovoice across the 2 years. These reflections exemplify the continuum on which projects can span, ranging from the lower rungs of the ladder of participation dominated by adult decision making, toward the higher rungs in which decision making is shared among all participants (Hart, 1992).

Discussion

In this section, we discuss three critiques of science education that emerged from our reflections on the heuristic and narratives. **Table 1** details the six parameters and provides specific examples from the narratives that align with each parameter.

Through critical dialogues on the narrative analyses and the heuristic parameters, we identified three intersecting critiques of science education in the service of neoliberalism that emerged through reflecting on the teaching and research practices recounted in these narratives: the assumed neutrality of teaching, the purpose of science education, and the need for reflection and reflexivity. We discuss each critique in relation to our Crit-Trans heuristic.

Table 1. Critical transdisciplinarity in action.

Parameter	Description	Example From Data
Contextualize and Historicize Knowledge	Recognize that our social interactions, societal relations, and lived experiences are situated in and guided by historical, political, economic, and cultural systems.	The gardening program begins with a walking tour explaining the history of struggle within the program.
Challenge Assumptions of Neutrality and Objectivity Through Critical Inquiry	Question the racialized, classed, gendered and historical, as well as political and social relations in society, building on the premise that inquiry is intersectional.	Organizing to maintain the site of the garden illuminated the political and social relations concerning who controls public space.
Decenter Hegemonic Notions of Knowledge Production	Acknowledge and privilege students and their cultures as producers of knowledge. The content to be taught, learned and/or researched emerges from and is relevant to the lived experiences of youth and educators.	The evolving connection between photovoice and research shifted when critical dialogic spaces were created in the class.
Situate Place and Space	Value the teaching and learning interactions that take place within and across formal, informal and nontraditional settings. Accept that the places in which one inhabits and learns (i.e. schools, gardens, neighborhoods, home) are integral in influencing knowledge production.	Using Photovoice in the environmental science class enabled youth to explore their communities.
Privilege Process over Product	Teaching, learning and/or research unfolds through student/teacher/group critical dialogues. Investigate and establish connections between lived experiences and how they have been shaped by context, rather than merely meeting a particular standard.	Struggles in the community or in students' lived experiences shaped the investigations around the community garden.
Promote Participatory Teaching, Learning, and Research	Determine the direction of learning, discussion, analysis, and content selection collaboratively. There is fluidity in the process of teaching and learning shared by all participants.	The long reflexive arc of teaching and learning in the position of educator in a formal classroom evolved into a grounded yet flexible approach.

Political neutrality

How we choose to teach science is political, whether we acknowledge the politics of our pedagogy or not. It reveals our assumptions about learning, science, and our students. It makes evident our beliefs and what we value, as well as our biases and prejudices. By viewing science critically, we create a space for youth and educators to unpack and challenge their experiences. Through critical self-reflection we begin to understand and then challenge hidden curricula that we as teachers may unwittingly reproduce.

Incorporating Crit-Trans in science education reveals the political in local environments. It highlights the ways that students can come to view their local environments as contested spaces where power, culture, and knowledge intersect and are unfixed. The science classroom then becomes a space that values learning from others, encourages multiple ways of knowing, and reveals the ways that learning and growth outcomes are not universal for all students (Bang & Medin, 2010). Learning reaches beyond the confines of standardized exams to incorporate personal and emotional growth.

The purpose of science education

The two narratives raise many questions about the practice and purpose of science education: How do the ways in which we teach science send messages to youth about whose knowledge is valued? If we continue to teach science in a way that privileges a Eurocentric ontology, students leave school believing that science consists of already established, objective, and value-free facts. However, if we learn science in the context of our lived experiences, as youth and teachers in both narratives did, we begin to recognize the roles we could collectively play in addressing issues in our local communities.

Based on the premise that knowledge is co-created in praxis (Freire, 1993), collectively engaging in dialogue around shared activities and personal experiences helps develop conceptual frameworks through which to understand our lives and society. Engaging students in the process of knowledge production supports students' agency in selecting meaningful inquiries and designing action-research projects in order to explore possibilities that could lead to social and environmental change (Fox & Fine, 2013).

Reflection and reflexivity in liberatory models of teaching, learning, and research

Knowledge that is co-created in praxis by individuals, whose learning experiences have been shaped by neoliberal logic, necessitates ongoing, rigorous self-reflection, and reflexivity. Negotiations start with a sustained focus on the tensions and contradictions arising between the needs and perspectives of various stakeholders. Educators committed to taking up Freire's (1993) call for a liberatory pedagogy of empowerment may harbor unexamined assumptions about teacher authority, student autonomy, educational goals, and pedagogy. These tensions may make it difficult to share control of the learning environment with students and allow them to engage as authorities, researchers, and co-creators of knowledge (Shor, 2012). Such obstacles must be viewed and interrogated as part of the complex and ongoing work of liberatory practice.

Conclusion: unfurling the enclosure

Under the current system of neoliberal education reform, policy "experts," who are often far removed from education, dictate what happens in the classroom (Malin & Lubienski, 2015). Teachers receive these mandates in the form of curricula and standards tied to assessments, which are then deposited onto students in the name of improving performance on standardized exams as a

marker of equality. This reinforces the deficit discourses and the ideology of meritocracy, which serves to further marginalize minoritized populations. In recognition of our own complicity in such a system, we sought to let go of our authority over knowledge, content, and space, as well as our reproduction of the hegemonic ways of being and knowing, through adopting the Crit-Trans heuristic. This process was met with tensions and contradictions for educators accustomed to control and students habituated to achieving success by becoming adept at complying with expected outcomes. However, to transform science education, we had to let go of this traditional way of thinking about science education and instead focus on the lived experiences of our students as shaped by their environments.

We see the potential of a Crit-Trans approach in the current climate of education “reforms” that do more damage than good, especially to students who are already marginalized from equitable learning opportunities. As educators, we rejected ideas of control over student learning and moved toward learning alongside our students. Moving forward, our aim is to cultivate spaces where young people shift their “epistemological understandings of knowledge production” (Adams & Gupta, 2013, p. 102), and recognize the relevance of science in their everyday lives in ways that allow them to maintain their salient identities. These spaces not only exist in informal learning environments, but also could be created in formal learning environments where an educator moves to the periphery of her class and allows students to have more agency over their own learning through participatory means. These are spaces that are more meaningful and intellectually rewarding for both students and teachers.

When students, specifically minoritized students, come to recognize and value their ability to be producers of knowledge through a critical process, we move away from a society focused on economic competition toward one focused on equity, social justice, and polysemy in science.

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